

1 A LOCAL SWITCH FOR A BROADBAND MULTIMEDIA TELECOMMUNICATIONS  
2 SYSTEM

3 BACKGROUND OF THE INVENTION  
4

5 1. Field of the Invention

6 The invention relates to telecommunications. More  
7 particularly, the invention relates to a broadband  
8 telecommunication systems for voice, video, and data and  
9 specifically to a local switch for use therein.

10 2. State of the Art

11 One of the latest developments in telecommunications is  
12 broadband telecommunications in the home. Presently, many homes  
13 have had access to a wide variety of video via cable TV, access to  
14 voice communications by POTS (plain old telephone service) and  
15 access to the internet via a modem of some type. Until recently,  
16 the fastest internet connection available to most homes was the  
17 v.90 modem which uses POTS to achieve a downlink bandwidth of up  
18 to 53K and an uplink bandwidth of up to 33.6K.

19  
20 Recently two types of broadband services have become  
21 available for the home and small business. These are the "cable  
22 modem" and various types of DSL (digital subscriber line)  
23 services. Cable modems utilize the existing cable TV network to  
24 provide high speed internet access at rates twenty to forty times

1 that of a v.90 modem. DSL service involves various different  
2 standards whereby relatively high data rates are provided over  
3 existing POTS lines. It will be appreciated that cable modem  
4 service is available through cable TV companies and DSL service is  
5 available though telephone service providers. Thus, cable TV  
6 companies compete with telephone service providers for high speed  
7 internet access customers.

8  
9 Changes in FCC regulations now permit cable TV companies to  
10 provide telephone service and permit telephone companies to  
11 provide cable TV-type service. Providing telephone services via a  
12 cable TV network and providing television programming via existing  
13 POTS lines each has different challenges which must be surmounted.  
14 Although the coaxial cable used by cable TV has a much higher  
15 maximum bandwidth (up to 4 gigahertz) than the copper wire known  
16 as "twisted pair" used by telephone companies, it is shared  
17 bandwidth. Shared bandwidth is perfectly well suited for  
18 unidirectional broadcast of television signals to many customers  
19 but is not well suited to bidirectional transmission of multiple  
20 voice and/or data streams. On the other hand, an unshielded  
21 twisted pair, which can provide 20-30 megahertz bandwidth for up  
22 to 3,000 feet, is more than adequate for bidirectional  
23 transmission of a single voice and/or data stream, but is  
24 inadequate for providing the hundreds of unidirectional video

1 streams which are available from cable TV companies. Thus, while  
2 cable TV companies are challenged with maintaining quality of  
3 service (QOS) when offering telephone and bidirectional data  
4 services, telephone companies are challenged with providing a  
5 broad selection of video streams when offering video viewing  
6 services.

7  
8 One solution to the challenge of offering both television and  
9 telephone service is for one company to control both the twisted  
10 pair and the coaxial cable for each customer. This solution  
11 overcomes the disadvantages of telephone service via shared  
12 coaxial cable and television service via relatively low bandwidth  
13 POTS lines. However, this solution is not truly an integrated  
14 solution and is costly to implement as it requires telephone  
15 companies to install coaxial cable for each customer and it  
16 requires cable television companies to install POTS lines for each  
17 customer. In both cases, companies are forced to work in areas in  
18 which they have no expertise.

19  
20 SUMMARY OF THE INVENTION  
21

22 It is therefore an object of the invention to provide methods  
23 and apparatus for broadband multimedia telecommunication.  
24

1 It is also an object of the invention to provide methods and  
2 apparatus for broadband multimedia telecommunication which  
3 includes combined voice, video, and data communications.  
4

5 It is another object of the invention to provide methods and  
6 apparatus for broadband multimedia telecommunication which  
7 maintains high QOS for voice and data while offering a large  
8 selection of different video streams.  
9

10 It is a further object of the invention to provide methods  
11 and apparatus for broadband multimedia telecommunication which are  
12 cost effective.  
13

14 It is an additional object of the invention to provide  
15 telephone companies with a single and straightforward system for  
16 competing with cable television companies in the integrated voice-  
17 video-data telecommunications market.  
18

19 In accord with these objects which will be discussed in  
20 detail below, the methods of the present invention include  
21 broadcasting a large selection of video streams via fiber optic  
22 cables over an ATM network to local switches. The local switches  
23 are coupled to customers by POTS lines and provide a predetermined  
24 number of (e.g. up to four) simultaneous video streams together

1 with high QOS voice and VDSL data service from the nearest local  
2 switch to each customer premises device. According to the methods  
3 of the invention, at each customer premises, the predetermined  
4 number of simultaneous video streams (out of hundreds available)  
5 are selected by signals from customer premises equipment to the  
6 local switch which transmits that number of different video  
7 streams from the local switch to the customer premises. According  
8 to the presently preferred embodiment, video, data, and digital  
9 voice service are provided via ATM (asynchronous transfer mode)  
10 cells from the network to the local switch where they are  
11 multiplexed with lifeline POTS service and transmitted to the  
12 customer premises via ATM cells.

13  
14 The presently preferred hardware of the invention utilizes  
15 CellBus® technology from TranSwitch Corporation, Shelton, CT.  
16 According to the presently preferred embodiment, the local  
17 switches each have four CellBus® backplanes supporting up to three  
18 OC-12 (or twelve OC-3) network connections with one backplane  
19 being redundant. Each local switch supports up to ten VDSL line  
20 cards, each supporting up to sixteen VDSL lines. The maximum  
21 bandwidth of each local switch is approximately 2.5 gigahertz  
22 which supports one hundred sixty VDSL connections as well as up to  
23 two hundred twenty theater quality MPEG-2 video streams or up to  
24 440 standard quality MPEG streams or a combination of standard and

1 high quality streams. Customer premises equipment according to  
2 the invention include a high speed modem which couples a personal  
3 computer to the customer's POTS line, a residential gateway unit  
4 which supports up to six devices (computers, TVs, digital voice  
5 lines) in addition to the lifeline POTS service, and a set top box  
6 for coupling a conventional television to the customer's POTS line  
7 or to the residential gateway. According to the presently  
8 preferred embodiment, the set top box is provided with enhanced  
9 functionality for accessing the internet, selecting from among  
10 hundreds of video streams including broadcast video and video on  
11 demand, etc. In order to conserve bandwidth within each local  
12 switch, multicast video streams are duplicated at the point  
13 closest to the customer.

14  
15 According to the invention, all broadcast video streams are  
16 delivered to the local switch for distribution as requested by  
17 customers. Unlike other digital video distribution systems,  
18 requests from customers for access to a particular video stream  
19 are not sent back to the video stream source, but are served by  
20 the local switch. According to a presently preferred method of  
21 the invention, when a customer requests a video stream, the  
22 request is sent to the VDSL line card which determines whether the  
23 selected stream is already being carried by that line card and  
24 duplicates the video stream at the line card if it is available.

1 If the video stream is not available at the line card, the line  
2 card creates a new video stream through the line card to the  
3 customer who requested it.  
4

5 Additional objects and advantages of the invention will  
6 become apparent to those skilled in the art upon reference to the  
7 detailed description taken in conjunction with the provided  
8 figures.  
9

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

11  
12 Figure 1 is a high level schematic diagram of a broadband  
13 multimedia communication system according to the invention;  
14

15 Figure 2 is a high level block diagram illustrating the major  
16 components of a local switch according to the invention;  
17

18 Figure 3 is a high level block diagram illustrating the major  
19 components of a core switch module of the local switch of Figure  
20 2;  
21

22 Figure 4 is a high level block diagram illustrating the major  
23 components of a system controller card of the local switch of  
24 Figure 2;

1  
2 Figure 5 is a high level block diagram illustrating the major  
3 components of a trunk (OC-3) interface card of the local switch of  
4 Figure 2;

5  
6 Figure 6 is a high level block diagram illustrating the major  
7 components of a VDSL line cards of the local switch of Figure 2;

8  
9 Figure 7a is a high level block diagram illustrating the  
10 major components of one type of customer premises equipment, i.e.  
11 a high speed internet interface;

12  
13 Figure 7b is a high level block diagram illustrating the  
14 major components of another type of customer premises equipment,  
15 i.e. a high speed internet interface with four derived (digital)  
16 voice lines;

17  
18 Figure 7c is a high level block diagram illustrating the  
19 major components of a digital set top box for use in conjunction  
20 with the customer premises equipment shown in Figures 7a or 7b;

21  
22 Figure 8 is a screen shot illustrating the user interface of  
23 the software used to configure the local switch and customer  
24 premises equipment;



Figure 9 is a schematic diagram illustrating how management information flows between the configuration software and a local switch;

Figure 10 is a schematic diagram illustrating how management information flows between the configuration software and the customer premises equipment;

Figure 11 is a schematic diagram illustrating how signalling and connection management information flows between the customer premises equipment and a service provider; and

Figure 12 is a schematic diagram illustrating how signalling and connection management information flows between the local switch and the customer premises equipment with regard to video streams.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Figure 1, a broadband multimedia communications system 10 according to the invention includes at least one local switch 12 which is coupled to one or more servers 14, 16, 18, 20 by one or more optical links 22 to one or more ATM

1 switches 24 as well as to the POTS network 26. A plurality of  
2 customer sites 28, 30, 32 are coupled to the local switch 12 by  
3 VDSL connections over unshielded twisted pairs 34, 36, 38 (e.g.,  
4 existing POTS lines). Each customer site is provided with at  
5 least one of several different types of customer premises  
6 equipment (described below with references to Figures 7a-7c) which  
7 enables multiple telephones, televisions, and personal computers  
8 to be coupled to the VDSL connection so that broadband multimedia  
9 communication may be effected as described in more detail below  
10 with reference to Figures 11 and 12. According to the presently  
11 preferred embodiment, each local switch 12, as well as customer  
12 premise equipment (described below), is remotely configurable by a  
13 computer 40 (shown to be coupled to the ATM network 24, but which  
14 may be located anywhere coupled to the internet) as described in  
15 detail below with reference to Figures 8-10. In addition, each  
16 local switch 12, as well as customer premise equipment (described  
17 below) is preferably provided with means for local configuration.

18  
19 Turning now to Figure 2, according to the preferred  
20 embodiment of the invention, the major components of the local  
21 switch 12 include four CellBus® backplanes 42, 44, 46, 48, two  
22 Ethernet LANS 50, 52, two physical buses 54, 56 and three  
23 different types of cards. The three different kinds of cards  
24 include a system controller card 58, a trunk interface card 60,

1 and a VDSL line card 62. Each of these three types of cards uses  
2 an identical core switch module 64, 66, 68 which is described in  
3 detail below with reference to Figure 3. The circuitry unique to  
4 the system controller card 58 is described in detail below with  
5 reference to Figure 4. The circuitry unique to the trunk  
6 interface card 60 is described in detail below with reference to  
7 Figure 5. The circuitry unique to the VDSL line cards is  
8 described in detail below with reference to Figure 6.

9  
10 According to the presently preferred embodiment, the local  
11 switch 12 has fifteen slots which accommodate (in subcombination)  
12 up to two system controller cards 58, up to eight trunk interface  
13 cards 60, and up to twelve VDSL line cards 62. The presently  
14 preferred embodiment utilizes three trunk interface cards, each  
15 being coupled to one CellBus® backplane and two system controller  
16 cards, each being coupled to all four CellBus® backplanes. One of  
17 the CellBus® backplanes is redundant and is only used to replace a  
18 failed CellBus® backplane. Only one system controller is active  
19 and the other is a backup in the event the active controller  
20 fails. As described in more detail below with reference to  
21 Figures 3 and 4, slots 7 and 8 are reserved for system controller  
22 cards which provide CellBus® clocking and arbitration. The other  
23 slots may accept either trunk interface cards or VDSL line cards.  
24 As described in detail below with reference to Figure 6, each VDSL

1 line card supports up to sixteen customers ("ports"). The  
2 following terminology is used elsewhere in this application when  
3 referring to scalable installations: a "node" is a group of local  
4 switches which have been "chained" together and a "shelf" is one  
5 of the local switches in the node.

6  
7 From the foregoing, it will be appreciated that each local  
8 switch 12 can support up to one hundred sixty customers. Due to  
9 the VDSL specification, customers may be located up to three  
10 thousand feet from a local switch 12. The local switches or nodes  
11 are preferably installed in telephone company central offices. In  
12 densely populated urban areas, a switch or a node may be located  
13 in an apartment building to service all of the apartment units.  
14 In suburban areas, if customers are too far from a central office,  
15 a switch or node may be installed in an equipment locker located  
16 closer to customers.

17  
18 Turning now to Figure 3, details of the core switch module  
19 (CSM) are seen. The CSM controls the transfer of ATM traffic  
20 between the backplanes and the card coupled to the module.  
21 Traffic flows toward the backplanes from the ingress cell MUX FPGA  
22 144 which receives ATM cells from a UTOPIA interface having four  
23 8-bit busses or one 16-bit bus. The cells are passed to a first  
24 header translator 122 where the ATM header is remapped according

1 to information stored in the translation RAM 120. The cells with  
2 new headers are then passed to the ingress cell distribution  
3 router FPGA 110 which routes the cells to the appropriate Cubit  
4 Pro® chip 88, 90, 92, 94 depending for which Cellbus® backplane  
5 the cells are destined. (The Cubit Pro® chip is available from  
6 TranSwitch Corporation, Shelton, CT.) Each Cubit Pro® chip has a  
7 multicast lookup table. Multicast cells have an 8-bit multicast  
8 ID which is used with the lookup table (on the receiving card) to  
9 determine multicast destinations for the cells (i.e. whether the  
10 cells will be accepted by the card). As described in more detail  
11 below, with reference to Figure 12, one of the methods of the  
12 invention uses the multicast tables and IDs to avoid wasting  
13 bandwidth with regard to video streams.

14  
15 Traffic flows from the backplanes through the Cubit Pro®  
16 chips 88, 90, 92, 94 to the Cellbus® MUX FPGA 112 where up to four  
17 streams are multiplexed together with the aid of a cell buffer  
18 114. The multiplexed stream of cells flows to a second header  
19 translator 118 which remaps the headers of the multicast cells  
20 according to information in translation RAM 116. The cells are  
21 buffered by the cell distributor 146 with associated RAM 148, 150  
22 before exiting the core switch module to a UTOPIA interface.

1       The core switch module includes other components which assist  
2 in the operations described above and which are used for other  
3 operations described below. These components include a power ramp  
4 circuit 70, reset generator 72, physical bus interfaces 74, 76,  
5 and a 4-bit slot ID/5-bit shelf ID storage 78. The physical bus  
6 interfaces 74, 76 as well as the physical bus (54, 56 in Figure 2)  
7 are used to sense when a card is plugged into and unplugged from  
8 the backplanes. The clock driver and arbiter blocks 80, 82, 84,  
9 86 shown in phantom lines in Figure 3 are only used with the core  
10 switch module coupled to the system controller card. They supply  
11 the 32 MHz CellBus® clock and the arbitration logic. Due to the  
12 CellBus® specification, the clock and arbiter should be located  
13 near the center of the bus. It is for this reason that slots 7  
14 and 8 reserved for the system controller card. The core switch  
15 module is also provided with a serial port 96 for locally  
16 configuring the switch as described in more detail below with  
17 reference to Figure 9. Ethernet access chips 98, 100 couple the  
18 cards to the Ethernet LAN (50, 52 in Figure 2) so that the I/O  
19 cards can communicate with each other and with the system  
20 controller card. The clock and clock driver 102 provides a 50 MHz  
21 clock for driving most of the data path.

22  
23       The BDM port 104 is a debugging port. The (Motorola)  
24 MPC860SAR 106 is the main processor which controls the ingress

1 cell router 110 directly as well as both PMC 7322 processors 118,  
2 122 via buffers 124. The PMC 7322 is available PMC-Sierra,  
3 Burnaby, British Columbia, Canada. The EPLD (erasable  
4 programmable logic device) 108 provides interrupts to the  
5 processor 106 based on the status of the physical bus, e.g. when a  
6 card is removed from a slot. The processor 106 utilizes SD RAM  
7 126, a boot flash RAM 128, and a main flash RAM 130. The boot  
8 flash RAM is used for booting the processor and the main flash RAM  
9 is used for nonvolatile storage of information other than boot  
10 information. An ID/Serial Number EPROM 132 stores a part number,  
11 an assembly serial number, a personality code, a MAC address, a  
12 component part number and a component serial number. The  
13 personality code indicates whether the card attached to the core  
14 switching module is a VDSL line card, a trunk interface card, or a  
15 system controller card. In the case of a line card, the  
16 personality code also indicates the number of modems (ports) on  
17 the line card, including any attached daughter card (explained  
18 below with reference to Figure 6). In the case of a trunk  
19 interface card, the personality code indicates the bandwidth of  
20 the card. Each core switching module also includes a temperature  
21 sensor 134, preferably placed near the hottest part of the board.  
22 The processor 106 receives input from the temperature sensor and  
23 generates an alarm if the temperature crosses a threshold. Each  
24 core switching module includes a Philips PCF8575TS CHIP 136

1 driving two seven segment LEDs 138, 140 which indicate diagnostic  
2 codes. The processor 106 includes an I<sup>2</sup>C controller 139 and an SPI  
3 controller 141 which are used to access features of the card  
4 coupled to the core switching module. A PCMCIA interface 142  
5 supports PCMCIA devices coupled to the card which is attached to  
6 the core switching module. See, e.g., 204 in Figure 4.

7  
8 Turning now to Figure 4, the system controller I/O card 58 is  
9 seen and includes a control FPGA 200, non-volatile RAM 202,  
10 removable flash disk storage 204, an LED controller display 206,  
11 five alarm relays 208a-208e, a craft port serial driver 210, an  
12 Ethernet transceiver 212, a power control circuit 214, a  
13 temperature sensor 216, and a personality code ROM 218. The FPGA  
14 200 is coupled to the RAM 202, the flash disk 204, the LED display  
15 206 and the alarm relays 208a-208e. In addition, the FPGA 200 is  
16 coupled to the core switch module (66 in Figure 1). Further, the  
17 FPGA 200 receives node alarm and status inputs 224 from and  
18 provides summary LED control 226 to the local switch (12 in Figure  
19 1) via a connection 220 to the backplane. Each of the alarm  
20 relays 208a-208e is bidirectionally coupled to the local switch  
21 via the backplane connector 220. The serial driver 210 is coupled  
22 to the craft port (Figures 9 and 10) in the local switch which  
23 enables an on-site technician to configure and/or troubleshoot the  
24 switch and/or its components. The Ethernet transceiver 212 allows



1 the system controller I/O card to communicate with network  
2 management software as described below. According to the  
3 presently preferred embodiment, the cards communicate via IP  
4 (internet protocol). The live insertion power control circuit 214  
5 is coupled to the power ramp circuit (70 in Figure 3) via power  
6 connector 222 to the backplane (Figure 3). The circuit 214  
7 permits "hot swapping" of cards on the backplane. The operation  
8 of the system controller I/O card, as well as the other cards, is  
9 described in detail below with reference to Figures 9-12.

10  
11 As mentioned above, the trunk interface cards (60 in  
12 Figure 2) may be configured in different ways to accept and  
13 support different OC connections. Figure 5 illustrates an  
14 exemplary Quad OC-3 trunk interface card 60. The card 60 includes  
15 four OC-3c transceivers 300a-300d which are coupled to a Quad OC-  
16 3c framer driven by a 19.44 MHz clock 304. The framer 302  
17 provides Utopia Level 2 data via the interface 306 and interboard  
18 connectors 308 to the core switch module (64 in Figure 2). An  
19 Intel microprocessor interface 310 is also provided via interboard  
20 connectors 308 to the core switch module. The Intel interface  
21 uses fewer pins than a Motorola interface. In order to conserve  
22 pin use, the Motorola interface is converted to an Intel  
23 interface. The trunk interface card 60 also includes a  
24 temperature sensor 312, a personality ROM 314, an LED display 316,

1 and a serial number ROM 318, each of which is coupled to the core  
2 switch module via an I<sup>2</sup>C bus interface 320 and interboard  
3 connectors 308. The I<sup>2</sup>C bus is a standard bus which is patented by  
4 Philips Semiconductors, Detroit, MI. As mentioned above, the  
5 personality ROM includes an indication about the type of card and  
6 its configuration. In the example shown in Figure 5, the  
7 personality ROM will indicate that the card is a trunk interface  
8 card with four OC-3 links. The trunk interface card 60 also  
9 includes a backplane power connector 322 which provides power to  
10 power ramp circuitry 324 which provides power to power filter  
11 circuitry 326. The operation of the trunk interface card, as well  
12 as the other cards, is described in detail below with reference to  
13 Figures 9-12.

14  
15 An exemplary VDSL line card 62 is shown in Figure 6. The  
16 line card 62 has four UTOPIA buses 400a-400d and a microprocessor  
17 interface 402. Each UTOPIA bus supports up to four VDSL modems.  
18 As shown, the line card 62 shown in Figure 6 only supports eight  
19 modems 404a-404h. In addition to the eight modems and interfaces,  
20 the line card includes a live insertion power control circuit 406  
21 which allows the card to be "hot swapped". The card also includes  
22 a temperature sensor 408, a personality ROM 410, and a serial  
23 number and revision number ROM 412, each of which is coupled to  
24 the microprocessor interface 402. An additional eight modems can

1 be added to this card via the use of a daughter card which couples  
2 to this card via a daughter card interconnect 414. Those skilled  
3 in the art will appreciate that the daughter card (not shown) will  
4 have substantially the same layout as the line card 62 but will  
5 share the same core switch module interface 416 and the same power  
6 circuit 406. The operation of the VDSL line card, as well as the  
7 other cards, is described in detail below with reference to  
8 Figures 9-12.

9  
10 The foregoing discussion all involves the portions of the  
11 invention outside of the customer's premises. According to the  
12 invention, various customer premises apparatus are provided by the  
13 invention and examples are described below with reference to  
14 Figures 7a-c.

15  
16 Figure 7a illustrates equipment 500 for providing high speed  
17 internet access and for linking to other customer premises  
18 equipment described below with reference to Figure 7c, for  
19 example. The equipment 500 includes a power module 502 which  
20 requires coupling to the customer's power mains and a VDSL  
21 connector 504 for coupling to the twisted pair which leads to the  
22 corresponding VDSL modem at the local switch. The VDSL connector  
23 504 supplies a connection to a POTS/ISDN splitter 506 which splits  
24 out the POTS/ISDN lifeline 508, and a connection to a VDSL modem

1 510. The VDSL modem 510 is coupled by an I<sup>2</sup>C bus to a Helium chip  
2 514 (available from Virata Corporation, Santa Clara, CA) and by a  
3 UTOPIA Level 2 bus 516 to both the Helium chip 514 and a CPLD  
4 (Complex Programmable Logic Device) 518. The Helium chip 514 has  
5 a peripheral interface 520, a protocol processor 522, SDRAM  
6 interface 524, a Utopia interface 526, a GPIO (general purpose  
7 input/output) 528, an Ethernet interface 530, and a network  
8 processor 532. The peripheral interface 520 is coupled to the  
9 CPLD 518 and the protocol processor 522. The SDRAM interface 524  
10 is coupled to the protocol processor 522, the network processor  
11 532, and to an offchip SDRAM 544. The Utopia interface 526 is  
12 coupled to the Utopia bus 516 and the network processor 532. The  
13 GPIO 528 is coupled to the I<sup>2</sup>C bus 512, the network processor 532,  
14 a terminal jack 534 for local configuration, an LED display 536,  
15 and a boot PROM 548. The Ethernet interface 530 is coupled to the  
16 network processor 532 and an Ethernet jack 538. The Helium chip  
17 also provides a JTAG interface 542 which is coupled to a JTAG jack  
18 540. As shown in Figure 7a, the CPLD 518 provides an ATM-25  
19 interface 550 for coupling to other customer premises devices such  
20 as the set-top box shown in Figure 7c. The CPLD is provided with  
21 flash RAM 546 and an LED display 552. In most instances,  
22 customers will couple a PC (not shown) or an Ethernet LAN to the  
23 Ethernet Jack 538 to obtain high speed internet access according

1 to the invention. The terminal jack and JTAG interface are used  
2 for configuration and debugging, respectively.

3  
4 Referring now to Figures 7a, 6, 3, 2, and 5, when a PC is  
5 coupled to the Ethernet jack 538 (Figure 7a), data (typically in  
6 the form of TCP/IP) flows bidirectionally through the Ethernet  
7 interface 530 to the network processor 532 where TCP/IP data is  
8 packed into and extracted from ATM cells. The ATM cells flow  
9 through the Utopia interface 526, Utopia level 2 516, the modem  
10 510, and the VDSL interface 504 to the appropriate modem 404  
11 (Figure 6) on the appropriate VDSL line card 62. The cells are  
12 routed via the Utopia bus 400 to/from the Cell Mux 144/Cell  
13 Distributor 146 on the core switch module 68 (Figure 3) associated  
14 with VDSL line card 62. The ATM cells containing TCP/IP packets  
15 flow together with the other ATM cells containing video, telephony  
16 data, etc. through an appropriate CubitPro 88, 90, 92, 94, to/from  
17 the appropriate CellBus bus 42, 44, 46, 48 (Figure 2) to/from an  
18 appropriate trunk interface card 60 (Figure 5). The trunk  
19 interface card receives cells from and transmits cells to the  
20 CellBus buses via the core switch module 64 (Figure 3) to which it  
21 is attached via the Utopia interface 306 (Figure 5). The cells  
22 are directed to/from an appropriate OC3c transceiver 300 via the  
23 Quad OC-3c framer 302. According to the preferred embodiment, the  
24 ATM connection between the trunk interface card and the Ethernet

1 interface 530 (Figure 7a) is provisioned as a PVC and is therefore  
2 "always connected". It will be appreciated that the POTS line 508  
3 is split off to the telco CO either at the local switch or at some  
4 point downstream of the switch.

5  
6 Figure 7b illustrates equipment 600 which is similar to  
7 equipment 500 with similar reference numerals, increased by 100,  
8 referring to similar parts. The equipment 600 differs from the  
9 equipment 500 by the inclusion of a DSP 654, a serial link  
10 interface card 656, and POTS emulators 658-664. The DSP 654 is  
11 coupled to the protocol processor 622 on the Helium chip 614 and  
12 to the interface card 656. It provides an analog to digital and  
13 digital to analog interface between the protocol processor 622 and  
14 the interface card 656. The POTS emulators 658-664 provide all of  
15 the analog signals of a regular POTS line so that regular POTS  
16 devices such as telephones, fax machines, modems, etc. can be  
17 coupled to the equipment 600. The DSP 654, converts analog  
18 signals from the POTS emulators to digital signals for use by the  
19 protocol processor 622 and converts digital signals from the  
20 protocol processor 622 to analog signals for use by the POTS  
21 emulators 658-664. The equipment 600 shown in Figure 7b provides  
22 up to four additional POTS lines via the POTS emulators and the  
23 DSP.

1 Referring now to Figures 7b, 6, 3, 2, and 5, when a telephone  
2 (or similar device, e.g. fax machine) is coupled to one of the  
3 derived POTS interfaces 658, 660, 662, 664, the interface provides  
4 a POTS emulation including ringing signals and dialtone. Analog  
5 voice signals from/to the POTS interfaces are muxed/demuxed by the  
6 four port SLIC 656 and converted from/to digital voice signals by  
7 the DSP 654. The digital signals are processed by the protocol  
8 processor 622 and passed from/to the SDRAM interface 624. The  
9 network processor 632 extracts digital voice data from ATM cells  
10 and places the data in the SDRAM 624. It also takes digital voice  
11 data from the SDRAM 624 and packs it into ATM cells. ATM cells  
12 containing digital voice data pass through the Utopia interface  
13 626, Utopia level 2 616, the modem 610, and the VDSL interface  
14 604 to the appropriate modem 404 (Figure 6) on the appropriate  
15 VDSL line card 62. The cells are routed via the Utopia bus 400  
16 to/from the Cell Mux 144/Cell Distributor 146 on the core switch  
17 module 68 (Figure 3) associated with VDSL line card 62. The ATM  
18 cells containing digital voice signals flow together with the  
19 other ATM cells containing video, TCP/IP packets, etc. through an  
20 appropriate CubitPro 88, 90, 92, 94, to/from the appropriate  
21 CellBus bus 42, 44, 46, 48 (Figure 2) to/from an appropriate trunk  
22 interface card 60 (Figure 5). The trunk interface card receives  
23 cells from and transmits cells to the CellBus buses via the core  
24 switch module 64 (Figure 3) to which it is attached via the Utopia

1 interface 306 (Figure 5). The cells are directed to/from an  
2 appropriate OC3c transceiver 300 via the Quad OC-3c framer 302.  
3 According to the preferred embodiment, the ATM connections between  
4 the trunk interface card and the POTS interfaces 658, 660, 662,  
5 664 (Figure 7b) are set up when needed as relatively low priority  
6 connections when a customer takes a telephone off hook and dials a  
7 number and when incoming ATM cells include voice data addressed to  
8 one of the POTS interfaces.

9  
10 Figure 7c illustrates a digital set-top box 700 suitable for  
11 use with either the equipment 500 shown in Figure 7a or the  
12 equipment 600 shown in Figure 7b. The set-top box 700 generally  
13 includes an ATM-25 interface 102 for coupling with the ATM-25  
14 interface 550 or 650 in equipment 500 or 600 respectively. The  
15 ATM-25 interface 702 is coupled to a PCI Bus 704. The components  
16 above the PCI bus in Figure 7c illustrate the components for  
17 receiving MPEG video signals and converting them into signals  
18 which can be displayed on a television set. An MPEG decoder 706  
19 is coupled to the PCI bus 704. The MPEG decoder 706 is provided  
20 with associated SDRAM 708 and provides a digital video output  
21 signal to an SVGA video card 710 having associated SGRAM 712. The  
22 digital signal from the SVGA card 710 is converted to an analog  
23 signal by a digital to analog converter 714 and is converted into  
24 an NTSC composite video signal by an NTSC encoder 716. A



1 composite video output is provided via an RCA jack 718 for  
2 coupling the composite video input of a VCR or TV/monitor. The  
3 MPEG decoder 706 delivers the audio portion of the signal to an  
4 audio decoder 720 which provides a digital audio signal to a  
5 digital to analog converter 722. The DAC 722 provides an analog  
6 audio output to an RCA jack 724 for coupling to the audio input of  
7 a VCR or TV/monitor. Though not shown in Figure 7c, the RCA jack  
8 724 is preferably two jacks, a left channel jack and a right  
9 channel jack, providing stereo analog audio channels. For  
10 television receivers which do not have composite video and analog  
11 audio inputs, an RF modulator 726 is provided. The RF converter  
12 receives composite video from the NTSC encoder 716 and analog  
13 audio from the DAC 722 and provides an RF output (typically  
14 switchable to either VHF channel 3 or 4) to an CATV coaxial cable  
15 connector.

16  
17 The components shown below the PCI bus in Figure 7c are used  
18 to select channels and otherwise interact with the set-top box. A  
19 PCI bridge 730 couples a CPU 732 and associate SDRAM 734 to the  
20 PCI bus 704. An ISA bridge 736 couples the PCI Bus 704 to an ISA  
21 bus 738, an IDE interface 740 and a USB interface 742. An I/O  
22 processor 744 and a v.90 modem 746 are coupled to the ISA bus 738.  
23 The I/O processor 744 is coupled to a BIOS 748, an IR port 750,  
24 and a parallel port 752. Basic operation of the set-top box 700

1 is via an infrared remote (not shown) which signals the set-top  
2 box via the IR port 750. The IDE interface 740, USB interface  
3 742, and parallel port 752 are provided for coupling the set-top  
4 box to other devices such as disk drives, keyboards, video games,  
5 digital video recorders, etc. The modem 746 is provided with an  
6 RJ-11 jack (not shown) for coupling to a phone line and is used  
7 for services which require a dial up connection, such as some  
8 directory and VCR programming services.

9  
10 As mentioned above with reference to Figure 1, the local  
11 switch and the customer premises equipment may be accessed  
12 remotely for configuration, status monitoring, testing and  
13 debugging, etc. Accordingly, as will be described as follows with  
14 reference to Figures 8-10, each device is assigned a unique IP  
15 address and is provided with an SNMP agent/subagent. A computer  
16 (e.g. 40 in Figure 1) provided with the configuration software of  
17 the invention addresses individual local switches as illustrated  
18 in Figure 8, communicates with the local switch as illustrated in  
19 Figure 9, and communicates with the individual customer premises  
20 units attached to the local switch as illustrated in Figure 10.  
21 The connection of the computer with the local switches and  
22 customer premises equipment may be remote via the internet or the  
23 ATM network or may be local via the Ethernet connections provided  
24 at each device.

1  
2 Referring now to Figure 8, the management software of the  
3 invention is preferably provided with a graphical user interface  
4 (GUI) 800. The GUI 800 includes window headers 802, 804, a tool  
5 bar 806, a network map view 808, a device status/configuration  
6 view 810, and an event monitor view 812. The window headers 802,  
7 804 includes standard buttons and menus familiar to all GUIs. The  
8 tool bar 806 includes small icons (buttons) for printing reports,  
9 accessing help, zooming in on a display, as well as other buttons  
10 for accessing features specific to the software of the invention.  
11 The network map view 808 illustrates all of the devices that are  
12 accessible to the software as well as the hierarchical path to the  
13 device currently being accessed by the software. As shown in  
14 Figure 8, the device being accessed has the network address  
15 192.168.100.102 and the contents of the device status/con-  
16 figuration view 810 indicate that the device is a local switch.  
17 The device status/configuration view 810 illustrates the various  
18 aspects of the device which are configurable and provides some  
19 status information.

20  
21 As shown in Figure 8, the device status/configuration view  
22 810 shows a local switch which has two trunk interface cards, one  
23 in slot 2 and one in slot 9, one system controller card in slot  
24 seven, and three VDSL line cards in slots 5, 11, and 12. All

1 other slots are empty. The status/configuration view 810 also  
2 illustrates (in the upper right portion) three alarms:  
3 temperature, fan, and intrusion as well as power supply unit (PSU)  
4 status. The temperature alarm indicates whether the ambient  
5 temperature is too high or too low for the equipment to function  
6 properly. The fan alarm indicates when the cooling fan  
7 malfunctions. The intrusion alarm indicates whether someone  
8 without authorization has attempted to tamper with the equipment.  
9 The PSU status indicates a power supply failure. The lower  
10 portion of the status/configuration view illustrates information  
11 about a selected one of the cards displayed in the upper portion  
12 of the view. As shown in Figure 8, the card in shelf one, slot  
13 twelve has been selected. Figure 8 illustrates that sixteen  
14 modems reside on the VDSL line card. Each modem is illustrated as  
15 an RJ-45 jack icon. A lamp icon next to each RJ-45 jack icon  
16 indicates if there is an alarm condition with respect to the  
17 respective modem. The status of the four buses coupled to the  
18 selected VDSL line card is also indicated to the left of the modem  
19 icons.

20

21 The event monitor view 812 includes a table (log) of  
22 information about noteworthy events in the network (not just the  
23 device selected in view 808). For each event, there is an  
24 indication of severity, date and time of the event, name of the

1 event, type of event, IP address of the device affected, and the  
2 shelf and slot location of the affected card, where appropriate.

3  
4 Using software with the graphical interface shown in Figure  
5 8, it is possible to configure a local switch as illustrated in  
6 Figure 9. As shown in Figure 9, client software 900, running on  
7 server 902 configures local switch 12 via the ATM switch 24 and  
8 the fiber optic link 22 using SNMP commands. As mentioned above,  
9 client software may be run on a computer which is locally coupled  
10 to the switch 12 via an Ethernet connection (212 in Figure 4). In  
11 particular, SNMP commands are sent through the trunk interface  
12 card 60 via the backplane 42-48 to a master SNMP agent 904 in the  
13 system controller card 58 which directs commands to sub-agents  
14 906, 908, 910 in a system controller card 58, trunk interface  
15 cards 60, and VDSL line cards 62, respectively. In this manner,  
16 each system controller card 58, trunk interface card 60, and VDSL  
17 line card 62 can be remotely configured, monitored, tested, etc.  
18 As shown in Figure 9, information is passed between the server 902  
19 and the master agent 904 via SNMP/UDP/IP/ATM and between the  
20 master agent and sub-agents via AgentX/TCP/IP. As illustrated in  
21 Figures 9 and 10, the client 900 may communicate with the server  
22 902 remotely using the Java communication protocol RMI (remote  
23 method invocation). Information flowing between the master agent  
24 904 and sub-agents 908, 910 on other cards, flows over the

1 Ethernet LAN 50, 52. The local switch 12 can also be configured  
2 via a craft interface 59 at the switch. The craft interface  
3 permits a technician to connect a portable computer to the switch  
4 via an RS-232 serial connection for configuration, testing, and  
5 trouble shooting with a command line interface.  
6

7 Figure 10 illustrates how SNMP commands from the client  
8 software 900 are sent to an SNMP agent 912 in a customer premises  
9 device 500. In particular, commands from the server 902 flow  
10 through the ATM switch 24 and the fiber optic trunk 22 to the  
11 trunk interface card 60 in the local switch 12. The trunk  
12 interface card 60 passes the commands via the backplane 42-48 to  
13 the appropriate VDSL line card 62 and the appropriate port 404 on  
14 the card to the SNMP agent 912 in customer premises equipment 500.  
15 According to the presently preferred embodiment, the address of  
16 customer premises equipment is given as a VPI/VCI from the VDSL  
17 line card. The network management software addresses the customer  
18 premises equipment with an IP address.  
19

20 Referring now to Figure 11, it should be noted that according  
21 to a preferred embodiment of the invention all broadcast  
22 television channels are brought to the local switch 12 via PVC  
23 (permanent virtual circuit) connections to the trunk interface  
24 cards 60 and thus all channels are always available simultaneously

1 to the local switch for transport to subscribers via the VDSL line  
2 cards 62. Other television streams, e.g. video on demand, are  
3 brought to the local switch via SVC (switch virtual call)  
4 connections or PVC connections. All video streams from the local  
5 switch to the subscribers are set up using the dynamic channel  
6 zapping protocol described below. As mentioned above, according  
7 to the presently preferred embodiment up to four different  
8 simultaneous video streams may be provided to each subscriber.  
9 The number four was chosen based on demographical information  
10 regarding the average number of television receivers per  
11 household. Those skilled in the art will appreciate, however,  
12 that more or fewer simultaneous video streams may be provided  
13 depending on the allocation of bandwidth between the customer  
14 premises and the local switch.

15  
16 Figure 11 generally illustrates that the system controller 58  
17 maintains PVC management information in non-volatile form (on a  
18 flash disk). The PVC management information is provided by the  
19 network management software or via the craft interface. When a  
20 trunk interface card 60 or a VDSL line card 62 is added to the  
21 system, the system controller card 58 sends connection management  
22 information (all of the information needed to set up and maintain  
23 PVCs) to these cards. The cards store the connection management  
24 information in memory used by the ATM translation chips so that

1 ATM cells flow properly with proper cell translation and tagging.  
2 If PVCs are added or deleted (new channels added, old channels  
3 removed) the PVC management information is altered in the system  
4 controller and the system controller automatically updates the  
5 trunk interface cards and the VDSL line cards. SVCs are  
6 established via ATM signalling between the customer premises  
7 equipment and the system controller 58 via a pass through  
8 connection (VC) in the line card 62 and between the system  
9 controller 58 and the ATM network switch (24 in Figure 1) via a  
10 pass through (VC) connection in the trunk interface card 60.  
11 Setting up and tearing down SVCs is performed by the system  
12 controller through connection management messages to the affected  
13 cards.

14  
15 Switching of streaming video connections between the local  
16 switch and the subscribers is handled by the VDSL line cards 62 as  
17 described in more detail below with regard to Figure 12. In the  
18 case of a non-broadcast (i.e. unicast) video stream, the switch  
19 controller 58 sets up an SVC connection between the local switch  
20 and a video service provider, e.g. 16, 18.

21  
22 Turning now to Figure 12 and with reference to Figures 7a and  
23 7c, when a customer selects a channel with the set top box 700,  
24 the customer premises equipment 500 requests a video stream by



1 designating the channel (e.g. 1-200) and designating a VPI/VCI  
2 (virtual path identifier/virtual circuit identifier) to be used by  
3 the VDSL line card (62 in Figures 2 and 6) to send the selected  
4 stream to the customer premises equipment 500 which passes it to  
5 the set top box 700 via the ATM-25 interface (550 and 702). The  
6 line card 62 (Figure 6) receives the channel request, in the form  
7 of one or more ATM cells via a modem 404 and passes the cell(s)  
8 via the UTOPIA bus 400 to its associated core switch module 68  
9 (Figures 2 and 3). The core switch module 68 receives the cell(s)  
10 via the ingress cell mux 144 which passes it to the PMC 7322 122  
11 for header translation. The ingress cell router 110 passes the  
12 cell(s) to the processor 106 which checks a channel blocking map  
13 in SDRAM 126 to determine whether the customer is entitled to  
14 receive the selected channel.

15  
16 If the subscriber is not already in "broadcast mode", i.e. if  
17 this is the first channel selection for the subscriber, the line  
18 card 62 requests permission from the system controller 58 via the  
19 Ethernet LAN 50, 52 to allow broadcasting to the designated  
20 subscriber. Using the control FPGA 200 (Figure 4) and associated  
21 memory 202, 204, the system controller 58 determines whether the  
22 viewer calling for broadcast mode is entitled to enter broadcast  
23 mode. If the system controller grants permission, the line card  
24 62 examines the bit maps in the CubitPro chips 88, 90, 92, 94 to

1 determine whether the selected video stream is already streaming  
2 through the line card to another viewer (whether the same or a  
3 different customer) coupled to this line card.  
4

5 If the stream is not already available on the same VDSL line  
6 card, the bitmap in the appropriate CubitPro chip is changed to  
7 enable the stream to be received from the trunk interface card 60  
8 via one of the CellBus buses 42, 44, 46, 48; and an entry is added  
9 to the egress translation table 116 to direct the stream properly  
10 to the correct VDSL port 404 and the originally designated VPI/VCI  
11 (i.e. the set top box from which the channel request originated).  
12 If the stream is already available on the card, an entry is added  
13 to the egress translation table 116 to allow for duplication of  
14 the stream and routing to the viewer who requested it.  
15

16 The protocol for managing channel changes and video streams  
17 between the customer premises equipment and the VDSL line card is  
18 based upon the DSM-CC (digital storage media command and control)  
19 SDB-CCP (switched digital broadcast channel change protocol) as  
20 adapted to the DAVIC (Digital Audio Visual Council) environment.  
21 The usage and the protocol stack differ, however. In the DAVIC  
22 environment, the CCP was intended to be used between the customer  
23 premises device and the video service provider. The goal of the  
24 SDP-CCP was to conserve network bandwidth by carrying over the

1 network only those video streams which are actually being viewed.  
2 According to the present invention, all available broadcast  
3 channels are carried on the network regardless of whether any are  
4 actually being viewed by a customer. Channels are selected for  
5 viewing by a customer by sending a message to the VDSL line card  
6 in the local switch rather than by sending a message over the  
7 network to the video service provider. This method of the present  
8 invention permits the combination of high QOS broadband internet  
9 service, high QOS voice telephony, and a broad selection of video  
10 streams all over the same medium.

11  
12 There have been described and illustrated herein several  
13 embodiments of methods and apparatus for broadband multimedia  
14 telecommunications. While particular embodiments of the invention  
15 have been described, it is not intended that the invention be  
16 limited thereto, as it is intended that the invention be as broad  
17 in scope as the art will allow and that the specification be read  
18 likewise. Thus, while particular "off-the-shelf" components have  
19 been disclosed, it will be appreciated that other components could  
20 be utilized. Also, while particular communications protocols have  
21 been shown, it will be recognized that other protocols could be  
22 used with similar results obtained. Moreover, while particular  
23 configurations have been disclosed in reference to alarms and  
24 other status information, it will be appreciated that other

1 configurations could be used as well. Furthermore, while the  
2 local switch of the invention has been disclosed as having a  
3 certain bandwidth, it will be understood that bandwidth may be  
4 expanded depending on the application. It will therefore be  
5 appreciated by those skilled in the art that yet other  
6 modifications could be made to the provided invention without  
7 deviating from its spirit and scope as so claimed.